STAR Measurement of the *W*-boson Single-Spin Asymmetry in Longitudinally Polarized Proton Collisions

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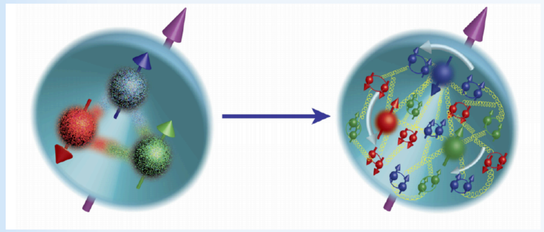
Motivation



$$< S_p >= \frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L$$

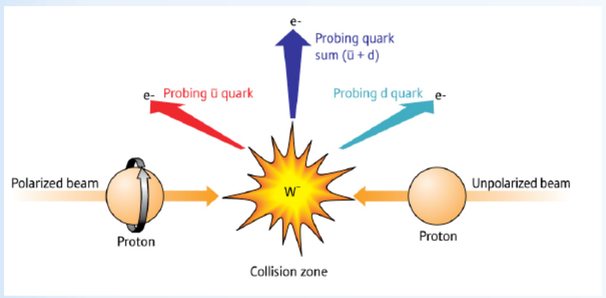
(Jaffe-Manohar, 1990)

$$\Delta\Sigma = \int (\Delta u + \Delta d + \Delta s + \Delta\bar{u} + \Delta\bar{d} + \Delta\bar{s})dx$$

- ❑ Proton spin is carried by quark and gluon spins, and orbital momentum
- ❑ Total quark and anti-quark spin contribution has been determined from inclusive DIS measurements
- ❑ **Polarized *W* measurement at RHIC is a unique way to delineate the flavor structure**

Polarized Parton Distribution Function of parton with flavor f: $\Delta f(x) = f^+(x) - f^-(x)$

Why *W*?



$$u + \bar{d} \rightarrow W^+ \rightarrow e^+ + \nu_e$$

$$d + \bar{u} \rightarrow W^- \rightarrow e^- + \bar{\nu}_e$$

Clean Spin and Flavor separation !

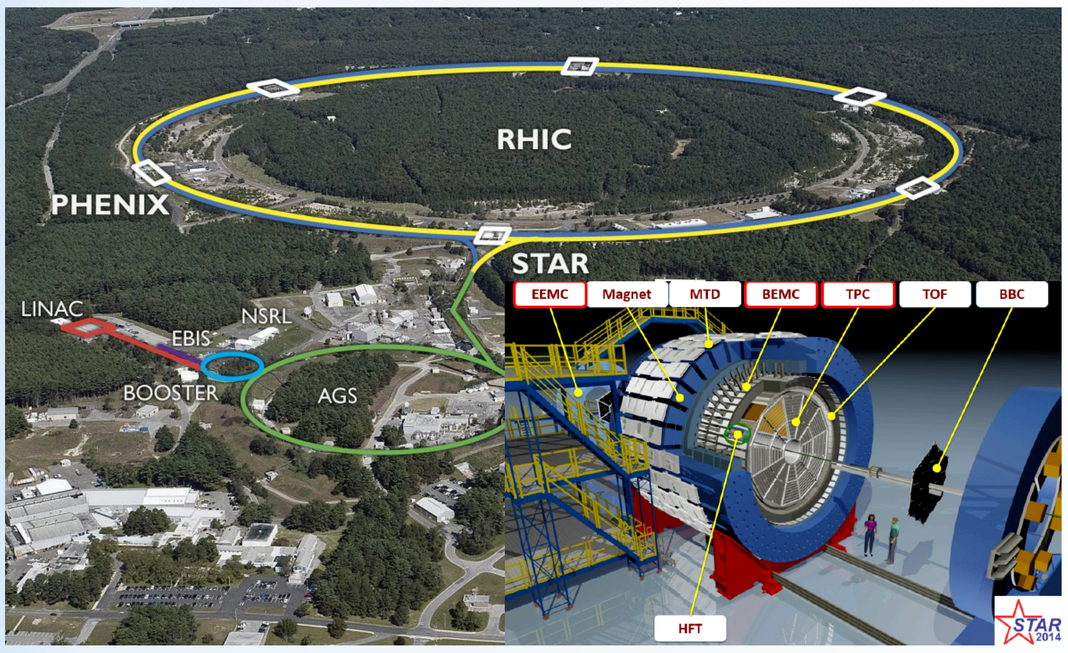
- ❑ *W* only couples with left-handed quarks and right-handed anti-quarks
- ❑ Leptonic decay is calculable and free of fragmentation uncertainties
- ❑ The high scale is set by the *W* mass, $Q \sim M_W$

$$A_L = \frac{\sigma^+ - \sigma^-}{\sigma^+ + \sigma^-}$$

$$A_L^{W^+} \propto \frac{-\Delta u(x_1)\bar{d}(x_2) + \Delta\bar{d}(x_1)u(x_2)}{u(x_1)\bar{d}(x_2) + \bar{d}(x_1)u(x_2)} \approx \begin{cases} -\frac{\Delta u(x_1)}{u(x_1)}, x_1 \gg x_2, & \text{forward} \\ \frac{\Delta\bar{d}(x_1)}{\bar{d}(x_1)}, x_1 \ll x_2, & \text{backward} \end{cases}$$

$$A_L^{W^-} \propto \frac{-\Delta d(x_1)\bar{u}(x_2) + \Delta\bar{u}(x_1)d(x_2)}{d(x_1)\bar{u}(x_2) + \bar{u}(x_1)d(x_2)} \approx \begin{cases} -\frac{\Delta d(x_1)}{d(x_1)}, x_1 \gg x_2, & \text{forward} \\ \frac{\Delta\bar{u}(x_1)}{\bar{u}(x_1)}, x_1 \ll x_2, & \text{backward} \end{cases}$$

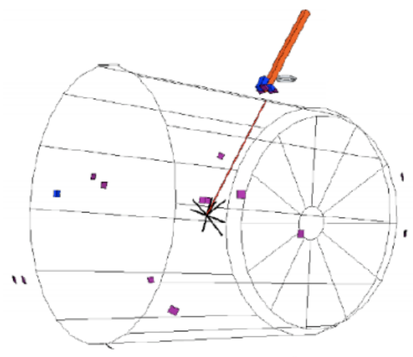
STAR Experiment and Data



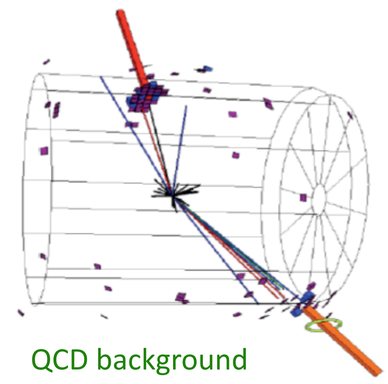
Data Sample of STAR Longitudinal pp collisions at √s = 500GeV:

- 330 pb^{-1} with 55% beam polarization, from 2011-2013

How is the *W* boson leptonic decay reconstructed?



W →e+ν signal



QCD background

Based on the kinematic and topological differences

- ❑ *W* leptonic decay contains an isolated high p_T electron opposite to large missing energy carried away by the neutrino
- ❑ Dominant QCD backgrounds are di-jet or multi-jet events

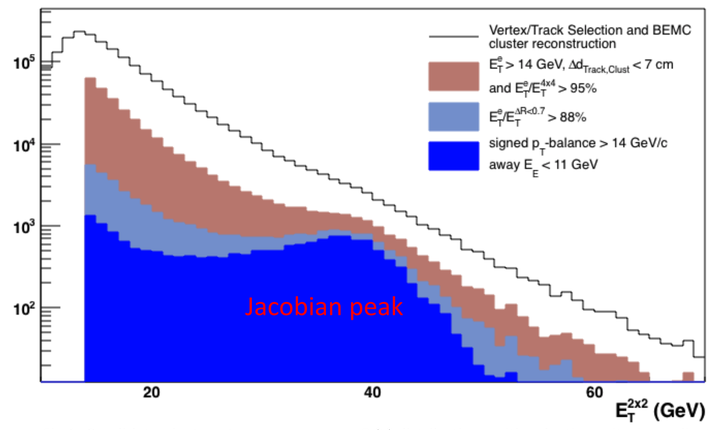


Fig 1: Candidate electron transverse energy E_T^{2x2} distributions with selection criteria application

Results

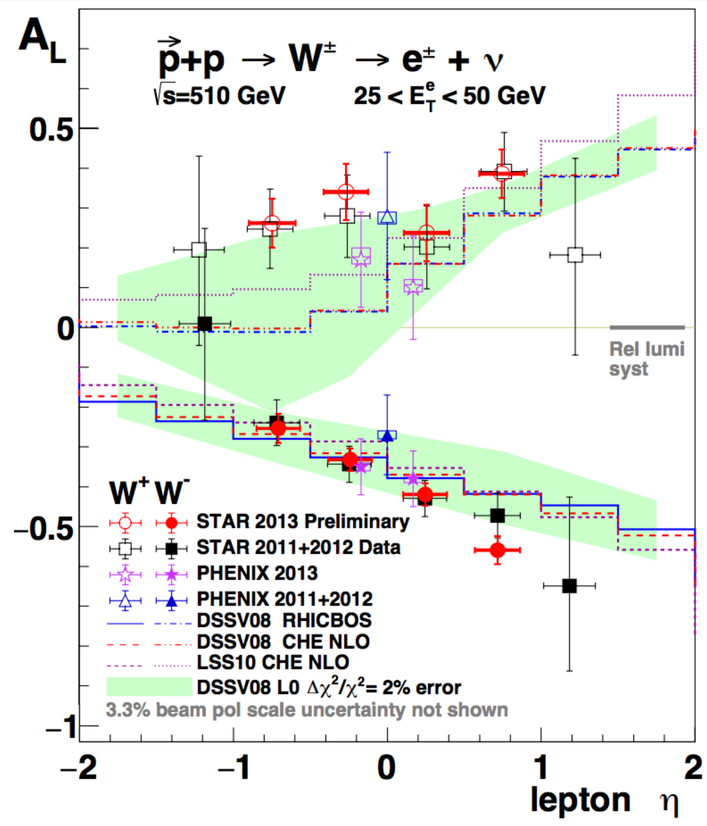


Fig 2: W A_L results as a function of lepton pseudo-rapidity from STAR 2011+2012 (black) and preliminary 2013 (red) with comparison to PHENIX W/Z A_L results and the theoretical predictions.

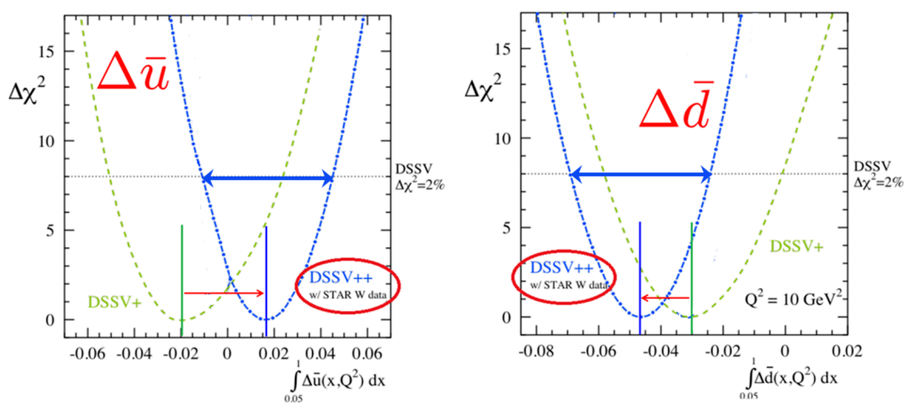


Fig 3: Impacts on light sea quark helicity distributions with STAR 2012 W A_L results and uncertainty projection from STAR 2013 W A_L results.

- ❑ STAR W A_L data are the most precise to date
- ❑ They favor $\Delta\bar{u} > \Delta\bar{d}$, opposite to the unpolarized light sea

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